

# **The DOE-NETL Air Quality Research Program: Airborne Fine Particulate Matter (PM<sub>2.5</sub>)**

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Office of Fossil Energy*

*National Energy Technology  
Laboratory (NETL)*



# Why DOE is Concerned About PM<sub>2.5</sub>

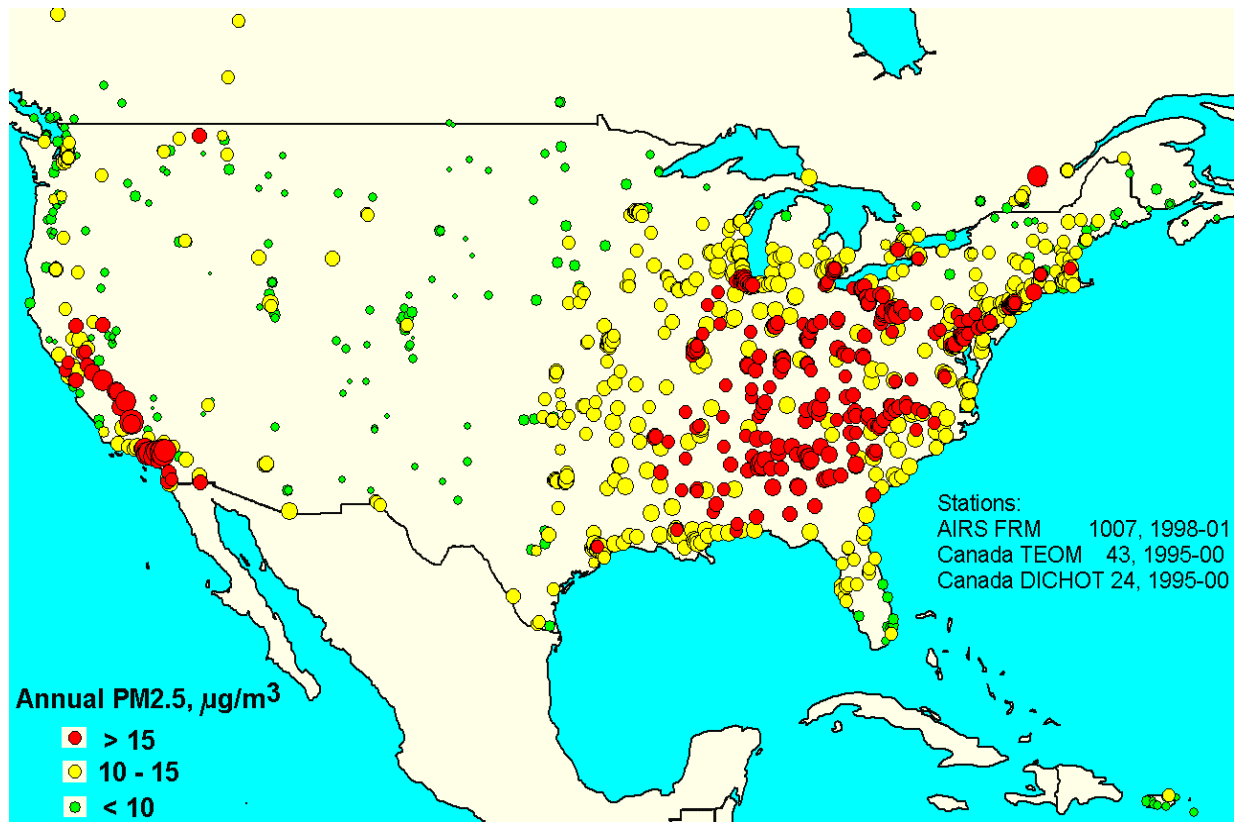
- **Goal 1 of Strategic Plan, DOE Office of Fossil Energy:**
  - “eliminate *environmental issues* as a barrier to fossil fuel production and use, while maintaining the *availability* and *affordability* of fossil fuels.”
- **Coal power emissions and PM<sub>2.5</sub> epitomize the complexities, challenges and tradeoffs**
- **Impetus for research: NAAQS for PM<sub>2.5</sub>**
  - Annual average: 15µg/m<sup>3</sup>; Daily maximum: 65µg/m<sup>3</sup>

# Coal Power & PM<sub>2.5</sub> - Central Issues

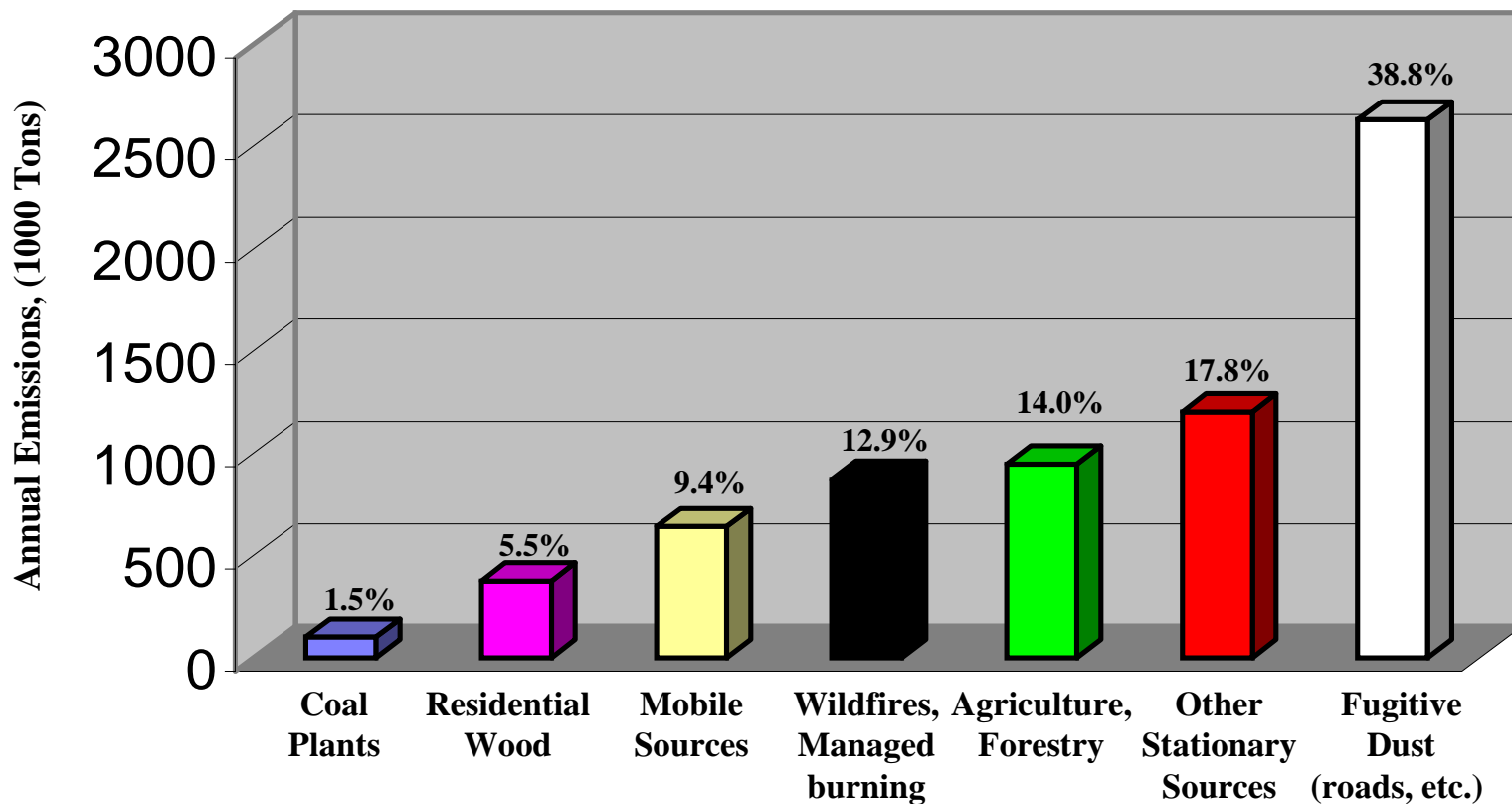
- **Primary vs. secondary PM<sub>2.5</sub>**
- **Mass vs. composition**
- **Multiple regulatory/legislative drivers**
- **Impacts of coal plant emission reductions**
  - NAAQS compliance (ambient PM<sub>2.5</sub> mass)
  - Regional Haze
  - Health effects



# Average Annual PM<sub>2.5</sub> Mass Concentrations (1995-2001)



# 1999 U. S. Primary PM<sub>2.5</sub> Emissions

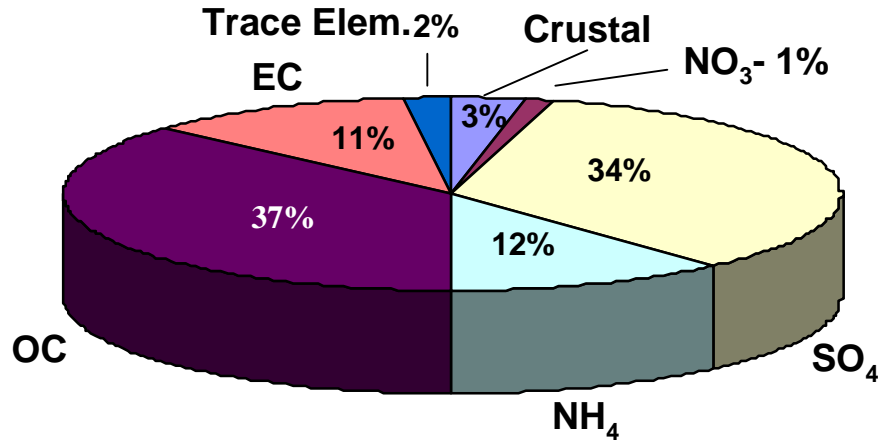


Source: National Air Pollution Emission Trends, 1999 (EPA-454/R-01-0049-80-009, March 2001)

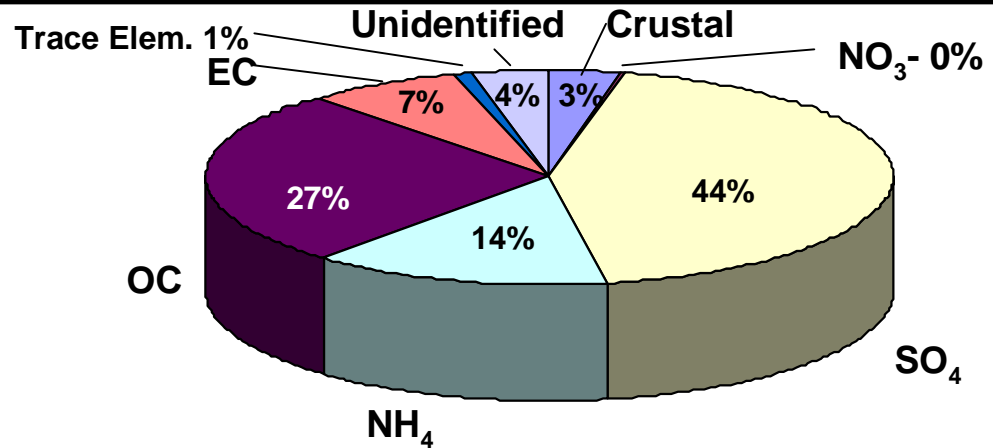


# Typical PM<sub>2.5</sub> Composition in Western PA (*Summer 1999*)

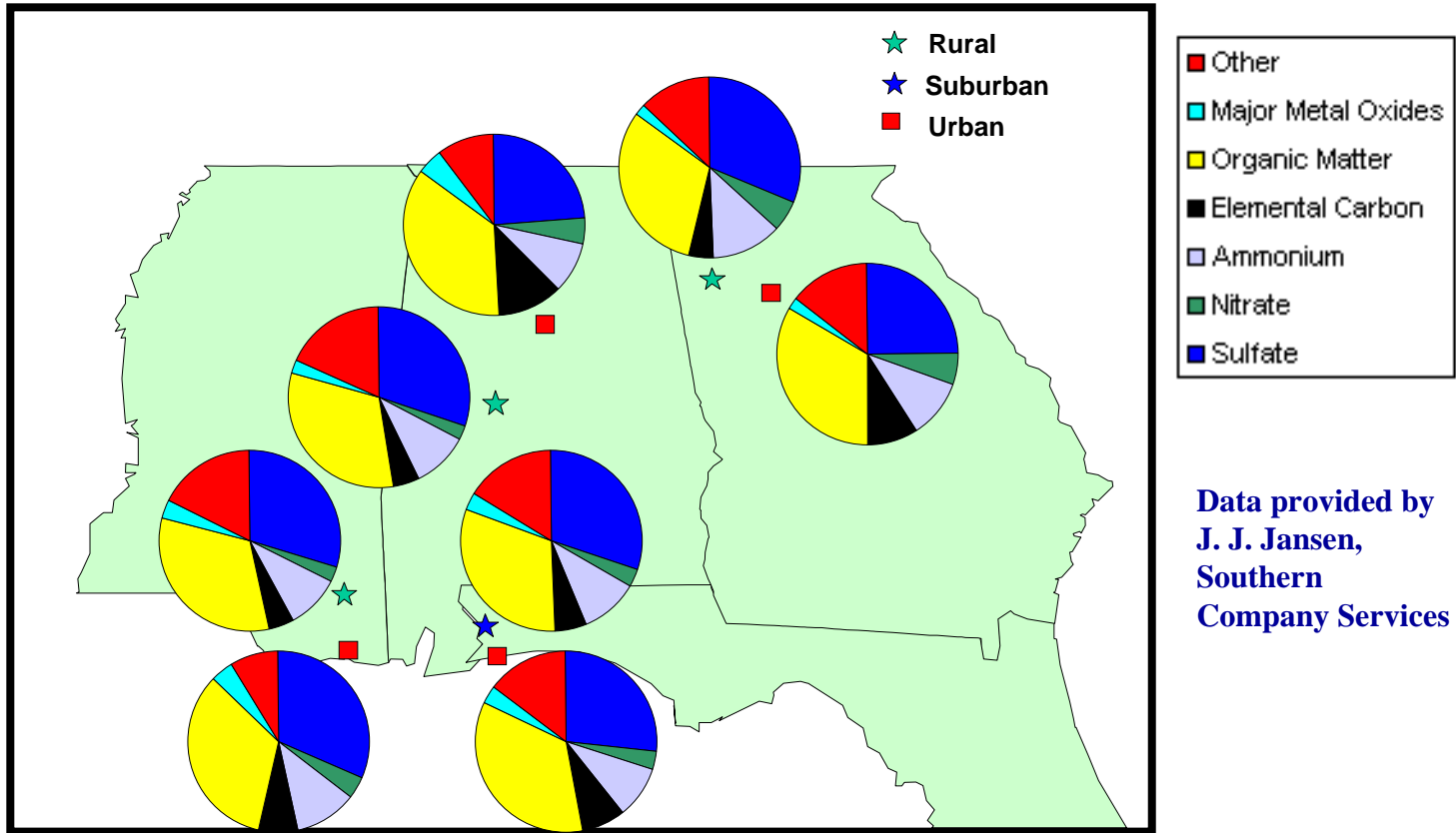
**Urban Site**  
(avg. of 39 samples)



**Rural Site**  
(avg. of 10 samples)

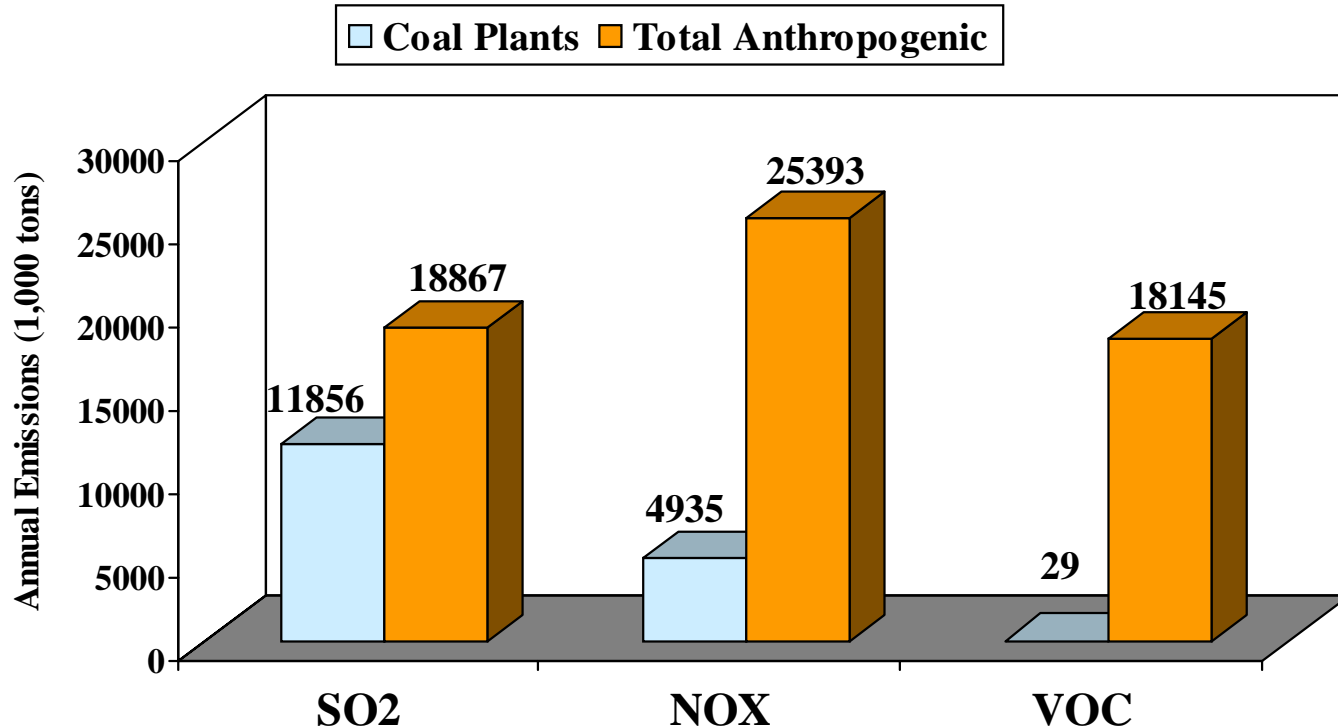


# PM<sub>2.5</sub> Composition in Southeastern U. S. (10/98 - 09/01)



Data provided by  
**J. J. Jansen,**  
Southern  
Company Services

# 1999 U.S. Secondary PM<sub>2.5</sub> Precursor Emissions



Source: National Air Pollution Emission Trends, 1999 (EPA-454/R-01-0049-80-009, March 2001)

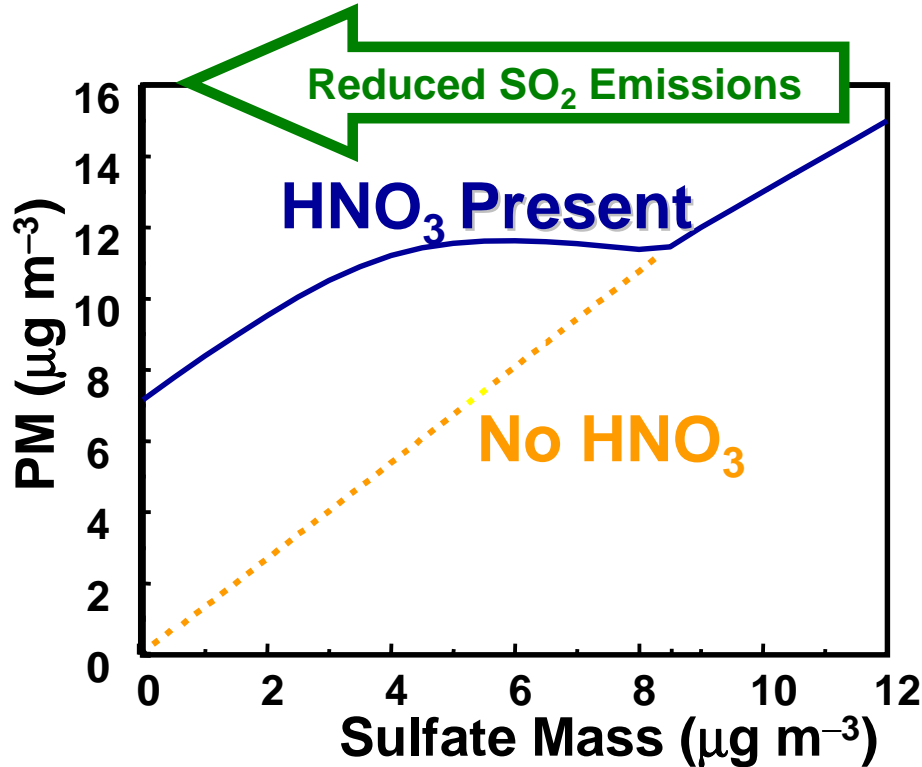


# **PM<sub>2.5</sub> NAAQS and Coal Plants**

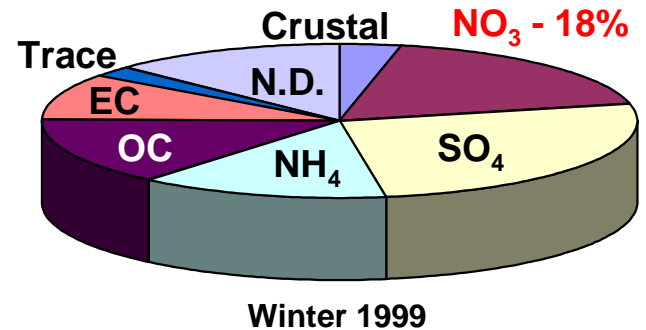
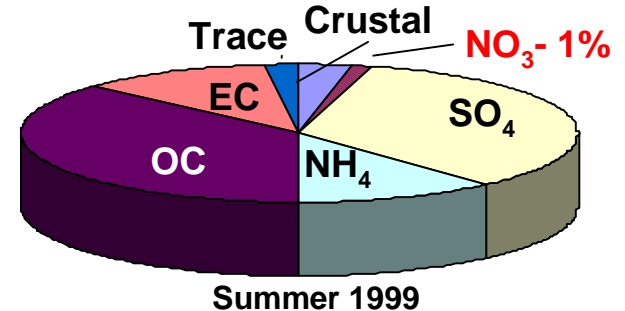
## **Considerations for SIP Development**

- **Reductions in primary PM<sub>2.5</sub> emissions will have minimal effect on compliance**
- **Reductions in coal plant emissions will not reduce carbon component of PM<sub>2.5</sub>**
- **Widespread restrictions on SO<sub>2</sub> emissions are a virtual certainty in Eastern U. S.**
- **Year-round reductions of NO<sub>x</sub> emissions also likely in Eastern U. S.**
  - Why NO<sub>x</sub>?

# Atmospheric SO<sub>4</sub> - NO<sub>3</sub> Interactions



## Pittsburgh PM<sub>2.5</sub> Composition



# Overlapping Regulatory/Legislative Drivers

- **NAAQS for Ozone: NO<sub>x</sub> SIP Call**
- **CAAA Title IV (Acid Rain)Phase II: SO<sub>2</sub> and NO<sub>x</sub>**
- **1999 Regional Haze Rule**
  - BART provisions for power plants(SO<sub>2</sub>)
- **NSPS: primary PM and stack opacity**
  - State/local reg's often more stringent than NSPS
  - May restrict release of acid gases (SO<sub>3</sub>)
- **Multipollutant legislation “Clear Skies Initiative”**
  - SO<sub>2</sub>, NO<sub>x</sub>, restrictions will affect PM<sub>2.5</sub> SIPs
- **Greenhouse gas emission restrictions?**

# What Will (Most Likely) Happen If We Reduce $\text{PM}_{2.5}$ and Precursor Emissions from Coal Plants?

- **$\text{SO}_2$  emission reductions will cause ambient  $\text{PM}_{2.5}$  sulfate to decrease**
  - Less regional haze, “Clear(er) Skies”
- **$\text{SO}_2$  and  $\text{NO}_x$  emission reductions may or may not reduce ambient  $\text{PM}_{2.5}$  mass**
  - Substitution of  $\text{NH}_4\text{NO}_3$  for  $(\text{NH}_4)_2\text{SO}_4$
  - $\text{NO}_x$  contribution from mobile sources
  - Significant carbon component of  $\text{PM}_{2.5}$



# What about Human Health Effects?

- Epidemiology suggests health will improve if PM<sub>2.5</sub> mass is reduced, but ...
- “Heterogeneity” of epi studies (City A ≠ City B)
  - Some components are more harmful than others
- Atlanta ARIES study (EPRI)
  - No association between sulfates and adverse health effects
- Very little information on toxicity of sulfates & nitrates vs. other common PM<sub>2.5</sub> components
- *Public needs accurate assessment of benefits (visibility vs. health) resulting from power plant emission cuts*

# DOE-NETL PM<sub>2.5</sub> Research Approach

- **Assumption: mass-based PM<sub>2.5</sub> NAAQS will remain in effect**
- **Relate emissions from coal-based energy production to concentrations and composition of ambient PM<sub>2.5</sub>**
- **Inform decision-makers about energy management options for achieving PM<sub>2.5</sub> and related air quality standards**

# Overview of DOE-NETL PM<sub>2.5</sub> Research

- Ambient Monitoring & Analysis
- Emissions & Plume Characterization
- Predictive Modeling & Evaluation

**Air Quality  
Research**

- PM/Acid Gas Control Technology R&D

- NETL Environmental & Water Resources Website

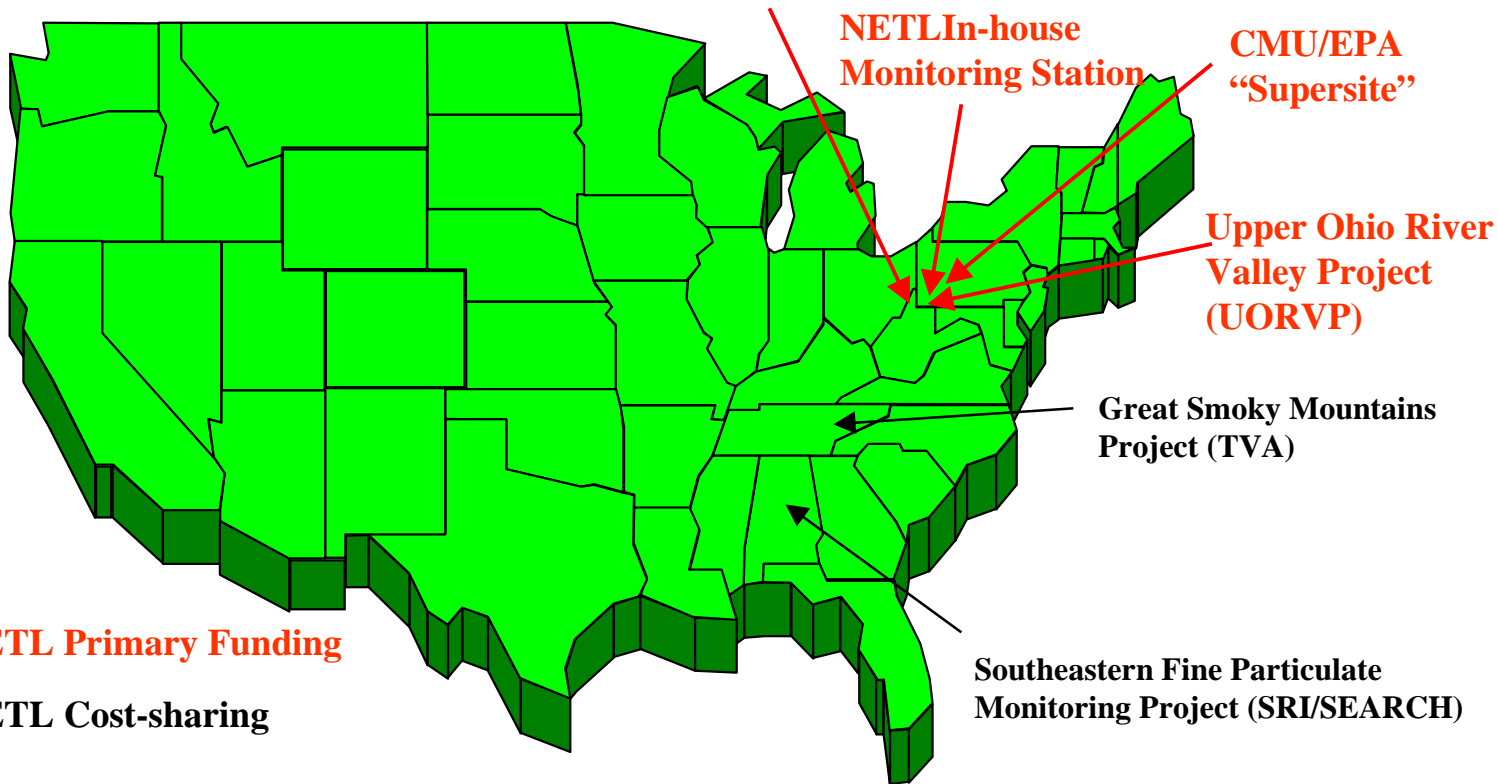
– <http://www.netl.doe.gov/coalpower/environment/>



# Ambient Monitoring and Analysis

## *Current Projects*

**Stuebenville Comprehensive Air Monitoring Project (SCAMP)**



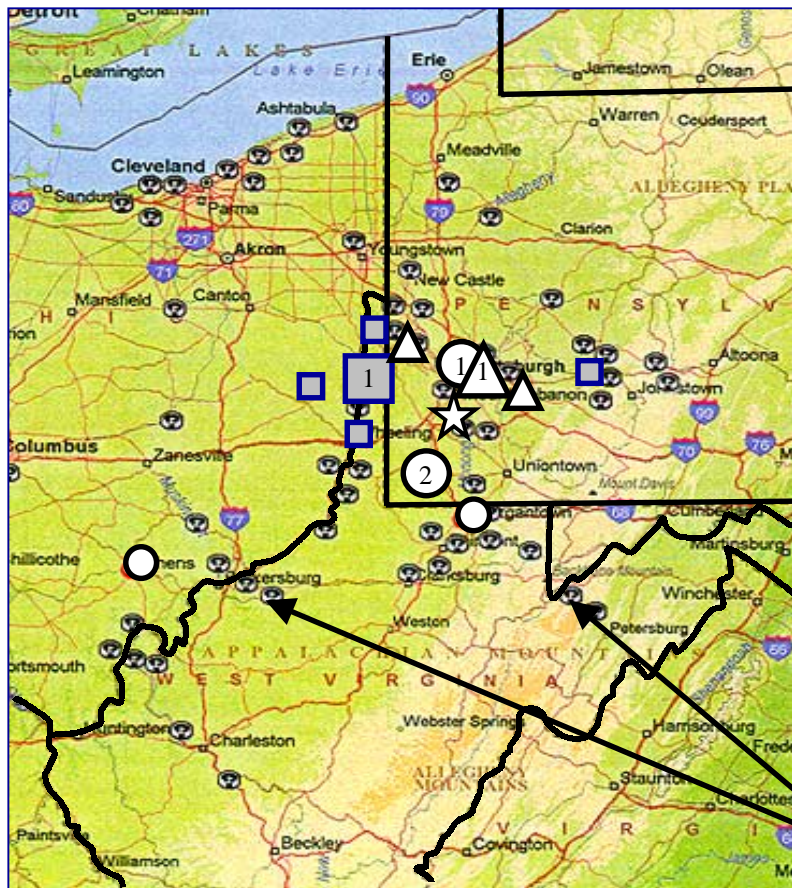
**DOE-NETL Primary Funding**

**DOE-NETL Cost-sharing**





# Ambient Monitoring Sites in Ohio River Valley



## UORVP Sites

- ① - Lawrenceville (Urban)
- ② - Holbrook (Rural)
- - Satellites

## SCAMP Sites

- 1 - Primary
- - Satellites

## EPA/CMU Supersite

- △ - Primary
- △ - Satellites
- ☆ - NETL In-house site

Coal-fired power plants



# Examples of Ambient Data Analysis

## Upper Ohio River Valley Project



**Lawrenceville (Urban)**



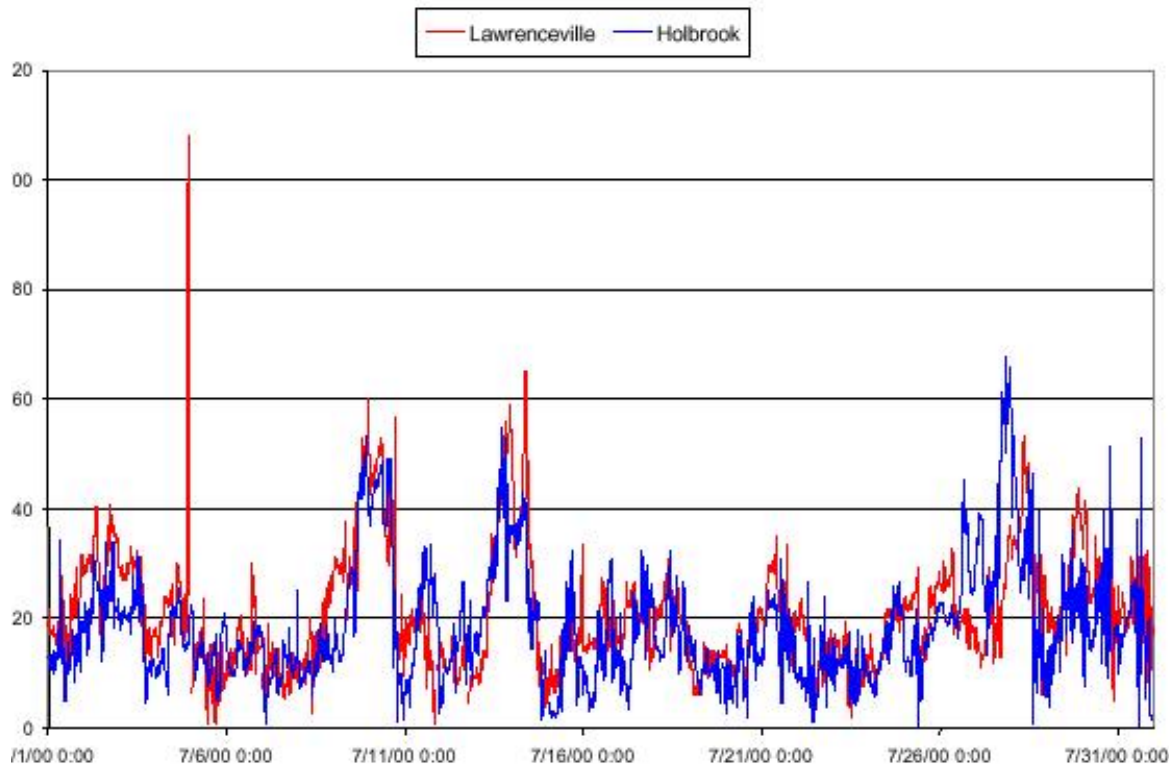
**Holbrook (Rural)**

- **Primary Performer: Advanced Technology Systems, Inc.**

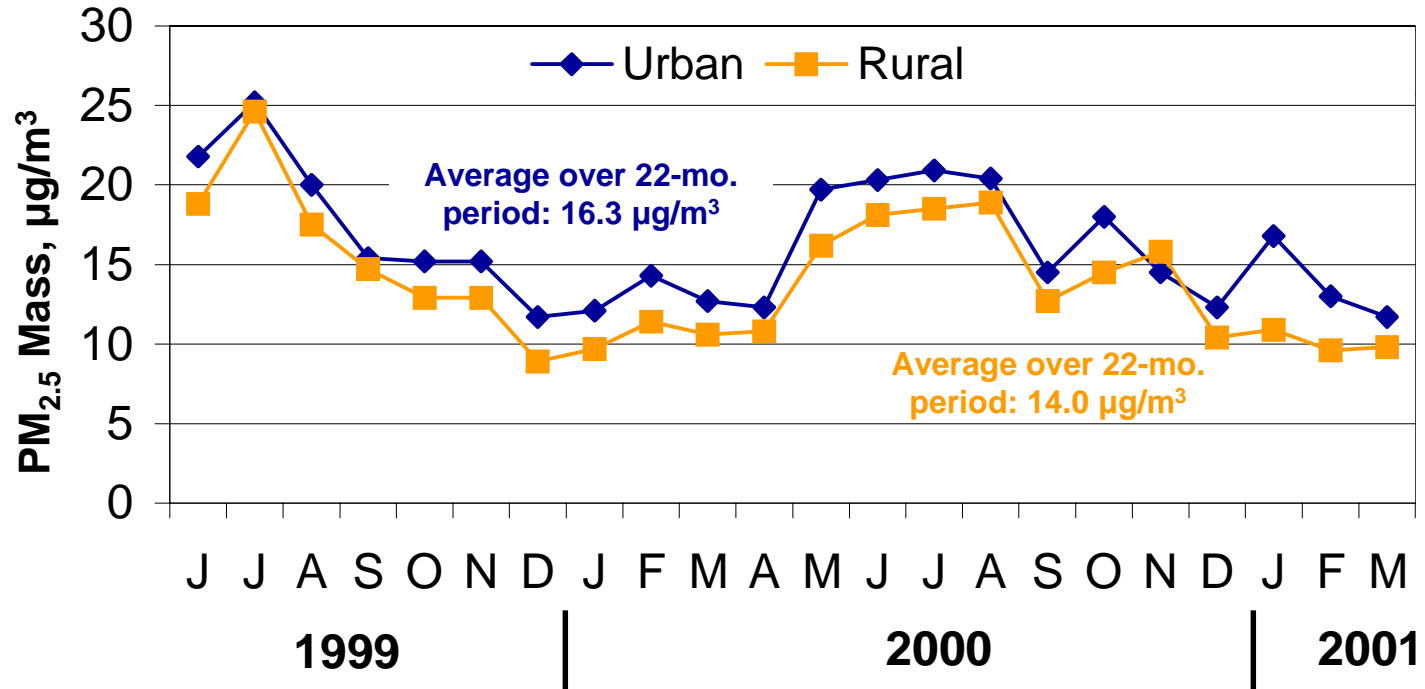


# PM<sub>2.5</sub> TEOM Data, July 2000

## *Urban-Rural Site Comparison*

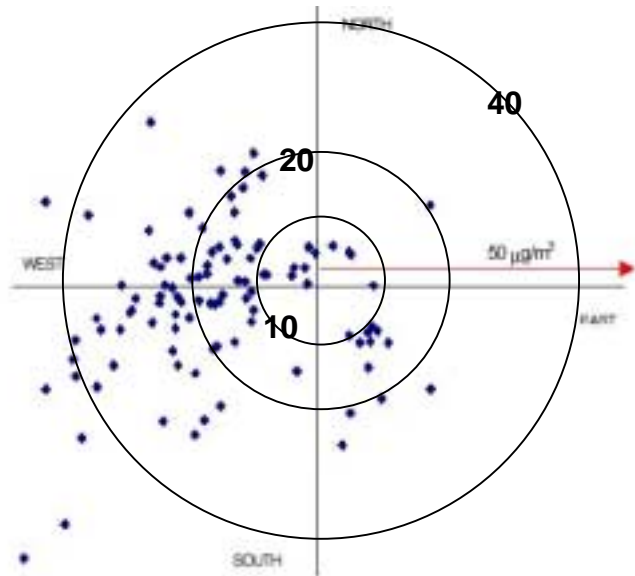


# Monthly Average TEOM PM<sub>2.5</sub>, UORVP Sites

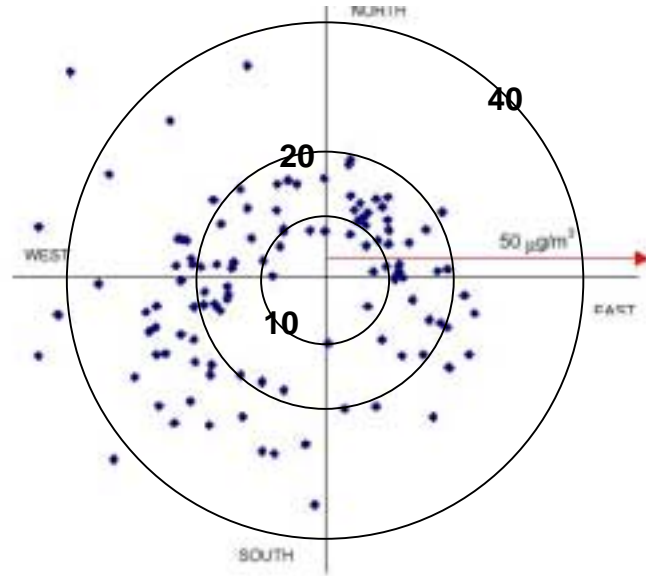


# PM<sub>2.5</sub> Mass vs. Wind Direction

July 1999



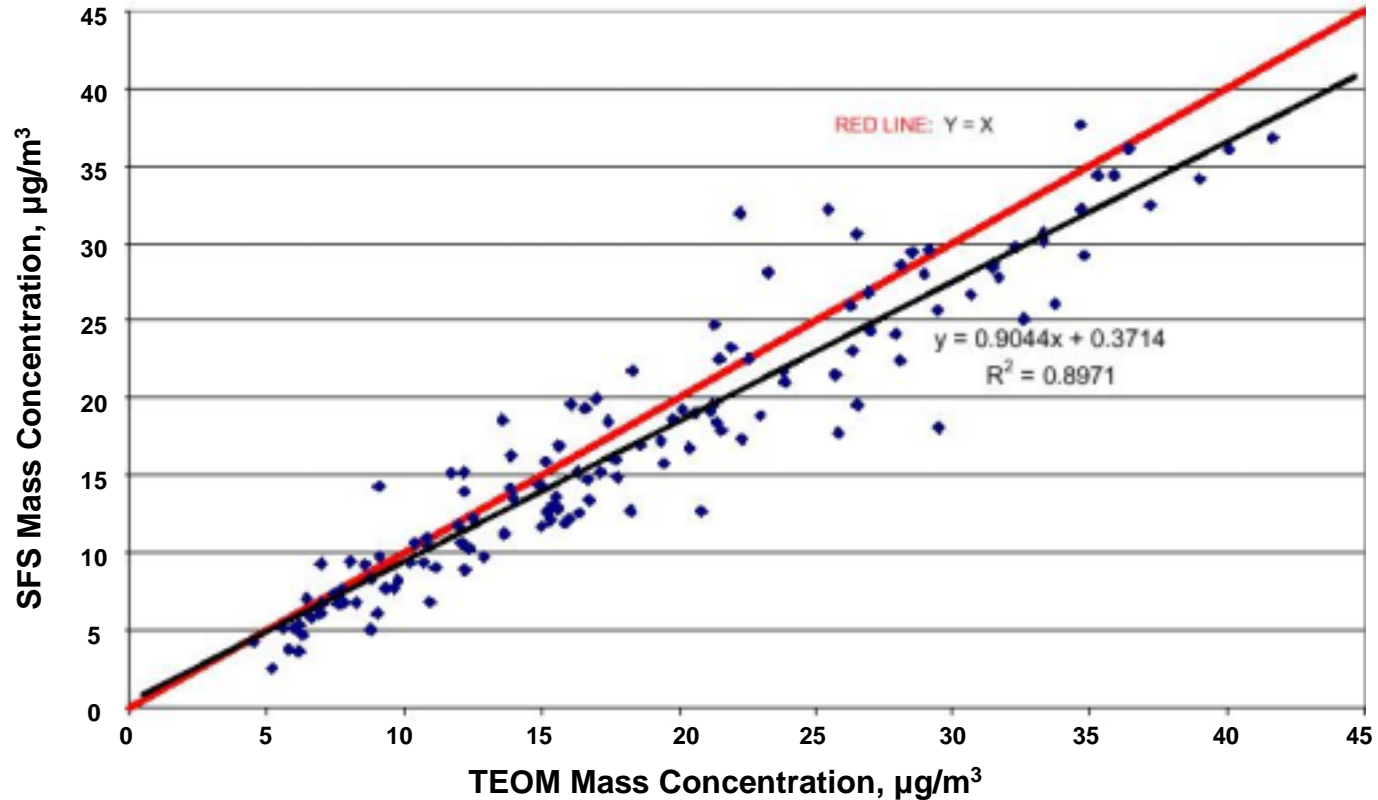
July 2000



Urban site, 6-Hr TEOM Averages,  $\mu\text{g}/\text{m}^3$

# PM<sub>2.5</sub> TEOM vs. Sequential Filter Sampler

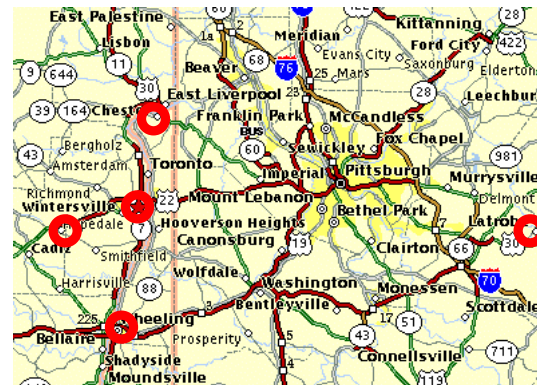
*6-Hour Samples, Urban site, Summer 1999*



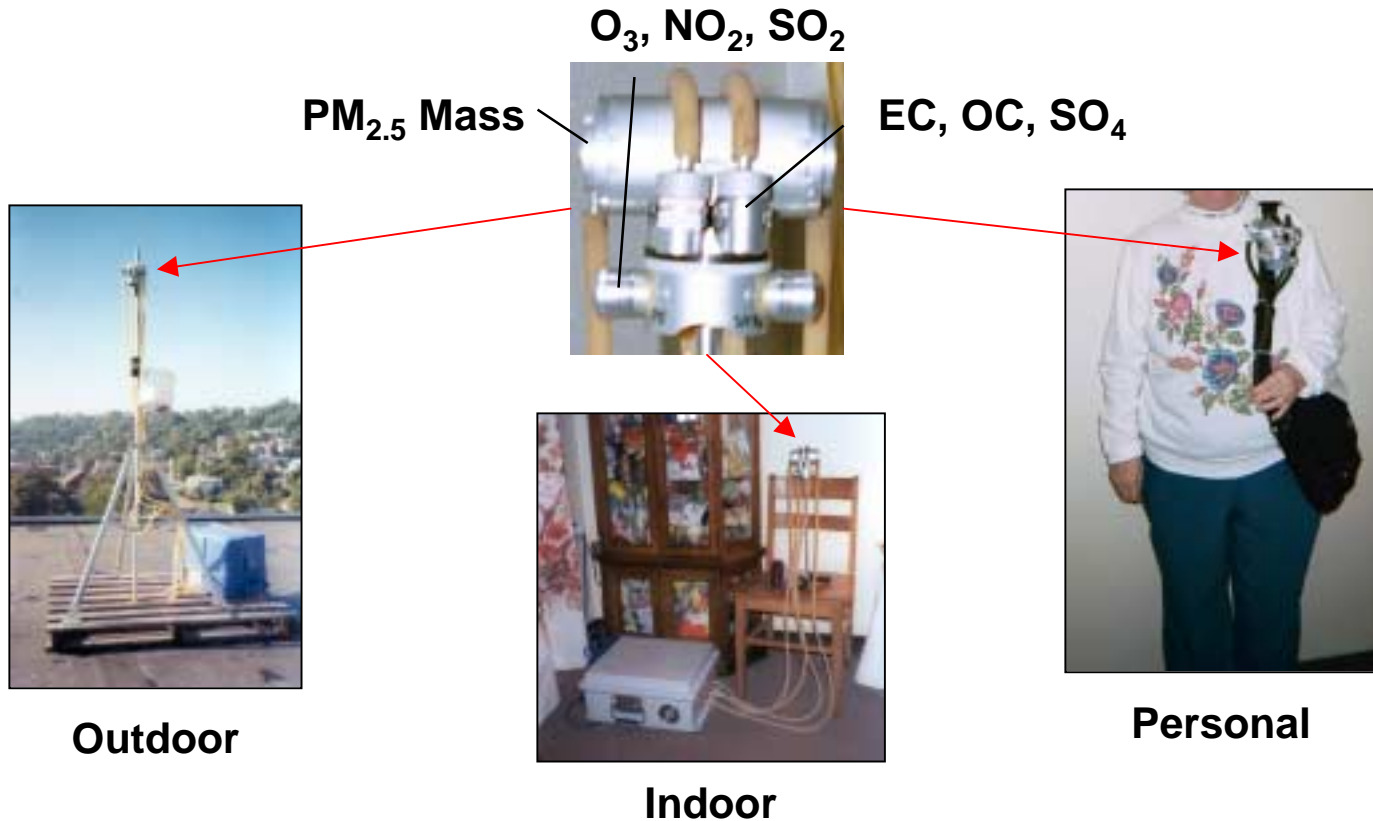


# Steubenville Comprehensive Air Monitoring Project (SCAMP)

- **Outdoor (Ambient) Study**
  - Primary performer: CONSOL, Inc.
  - Funding: DOE, EPA
- **Personal Exposure Study**
  - Outdoor vs. indoor vs. personal  $PM_{2.5}$  in Steubenville
  - Primary Performer: Harvard School of Public Health
  - Funding: Ohio Coal Development Office (OCDO), EPRI, NMA, API, AISI, CONSOL

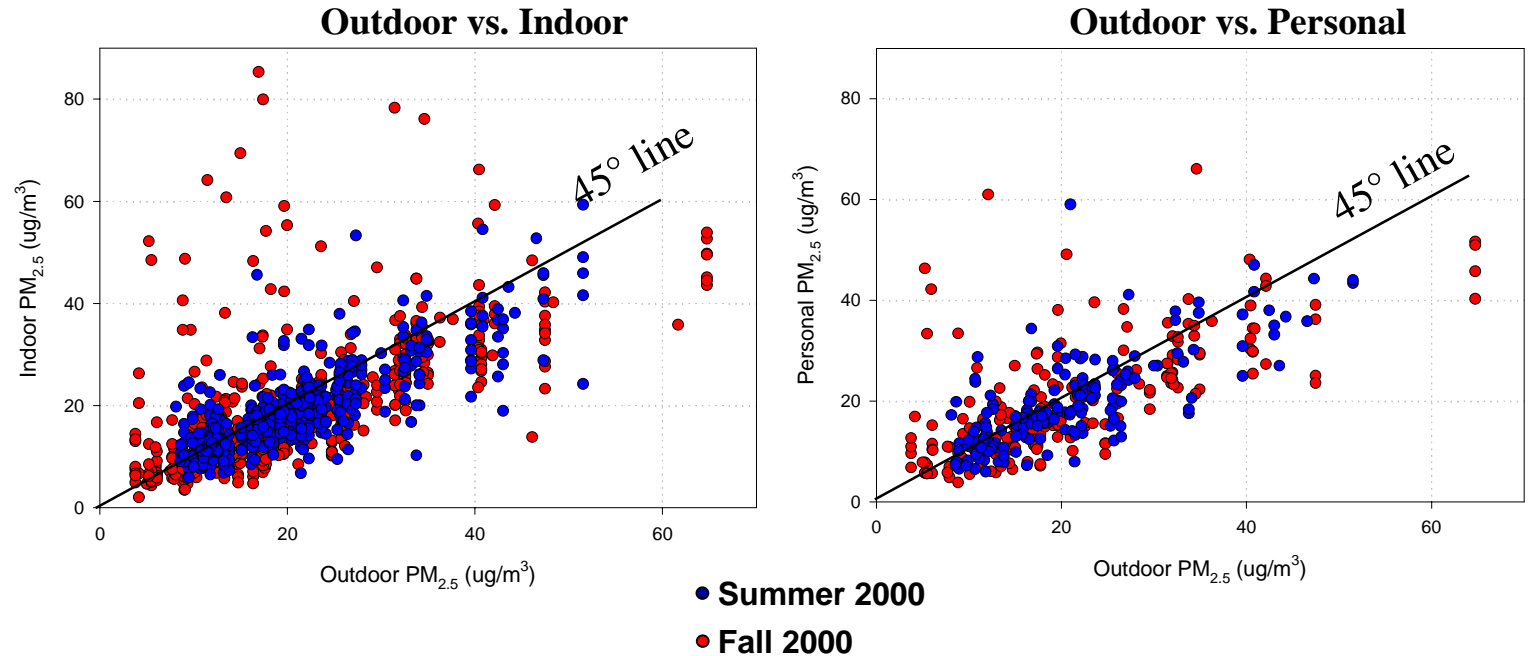


# Harvard Multi-pollutant Sampler - SCAMP





# Example of SCAMP Exposure Study Data



# **Pittsburgh Air Quality Study**

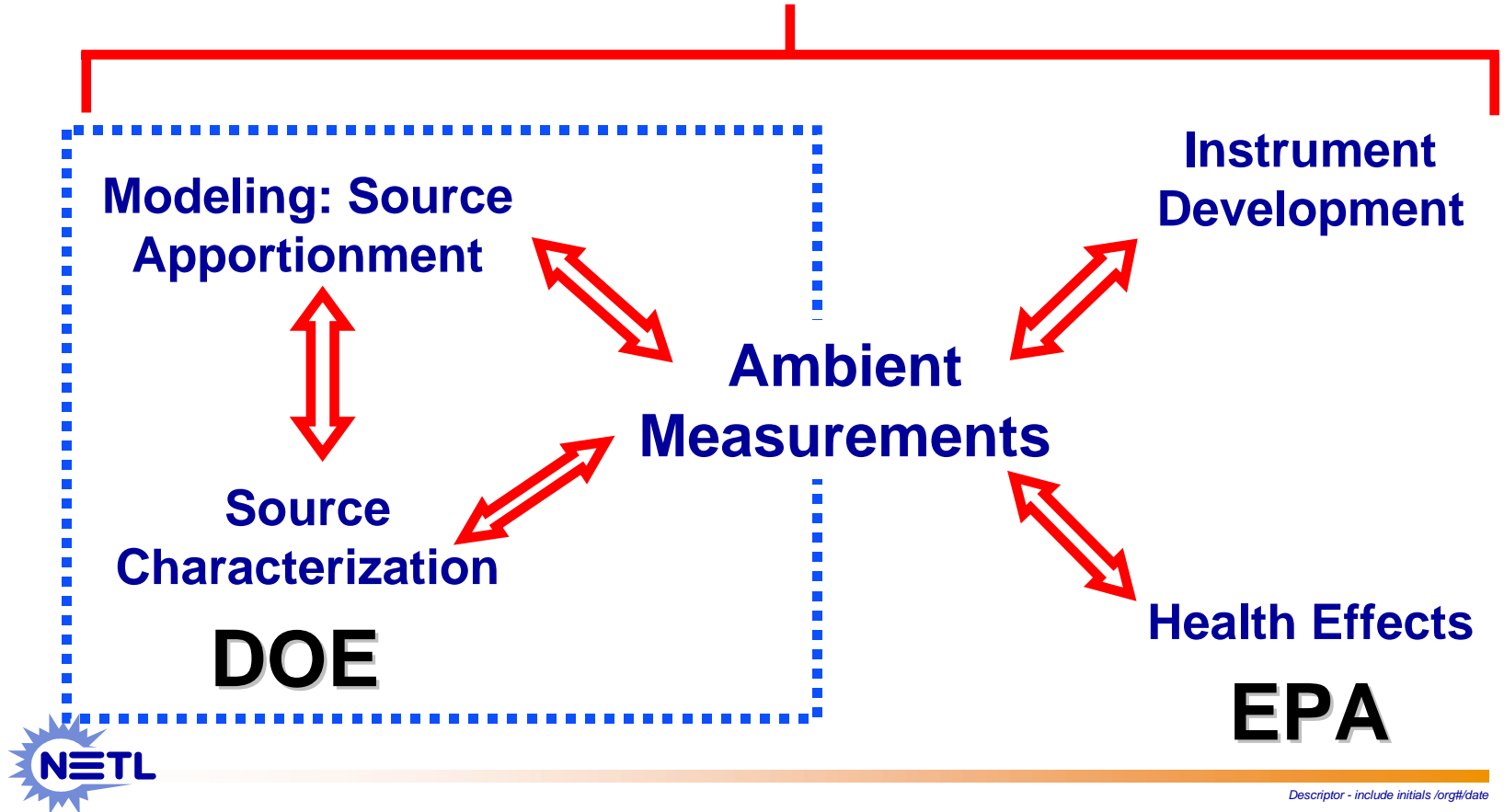
## *Carnegie-Mellon University*

- **Leveraged with CMU/EPA Supersite**
- **DOE Project Title: “Atmospheric Aerosol Source-Receptor Relationships: The Role of Coal-fired Power Plants”**
- **All 3 components of Air Quality Research:**
  - Advanced ambient monitoring at EPA “Supersite”
  - Source characterization/profiling in Pittsburgh area
  - Comprehensive regional modeling and data analysis









# CMU-Pittsburgh Air Quality Study

## *Objectives*



# CMU-Pittsburgh Air Quality Study

## DOE Project Schedule

	2001												2002												2003															
	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D							
Ambient Monitoring and Analysis																																								
Source Characterization																																								
Compile Inventories & Activity Levels																																								
Source Sampling w/Dilution Sampler																																								
Source Apportionment Modeling																																								
Three-Dimensional Modeling																																								
Final Report																																								



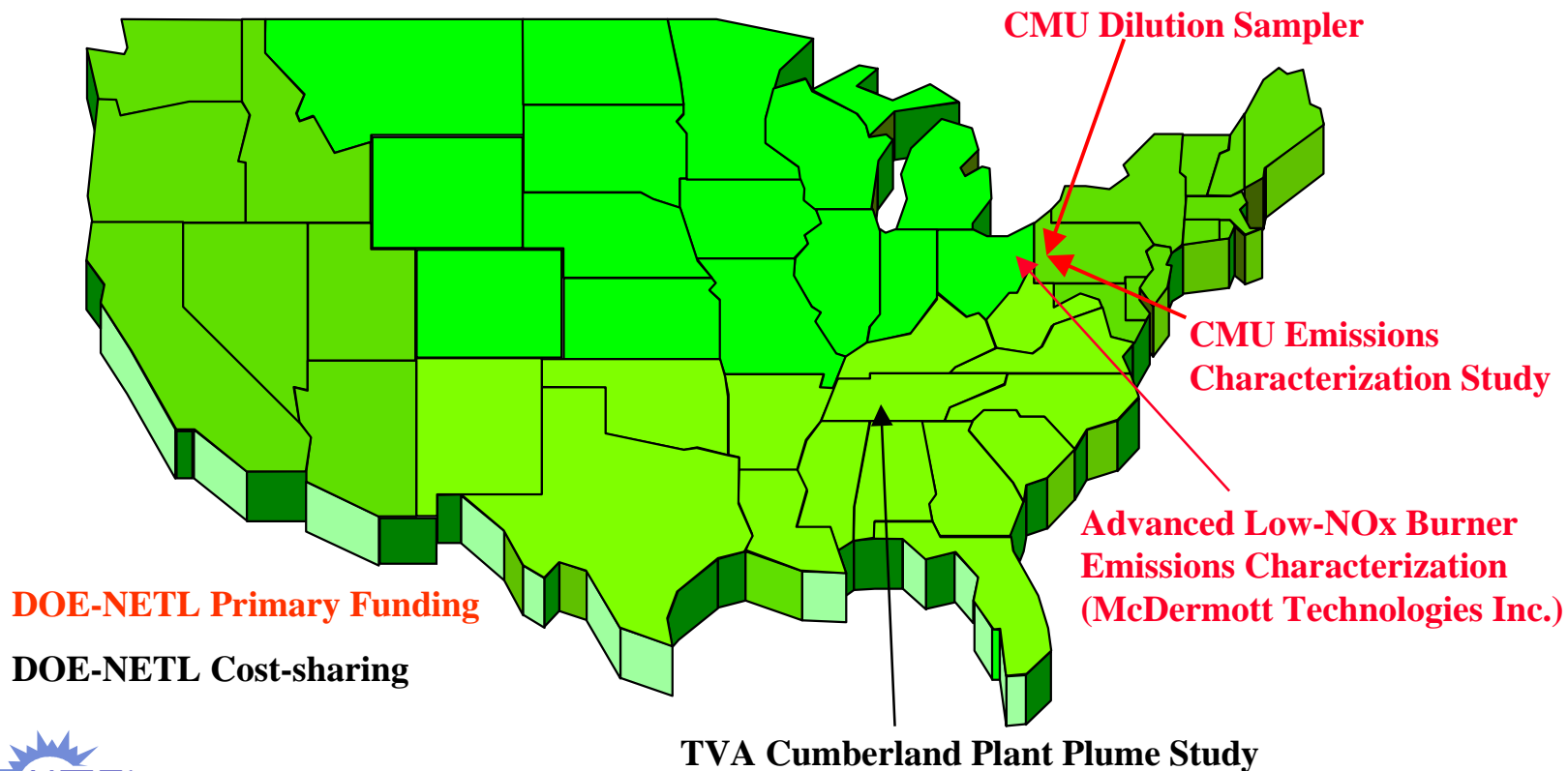
# Integrated Database and Analytical Tool

- **New Award to Advanced Technology Systems, Inc.**
  - Project start: August 2002
- **Integrate data from all DOE-NETL sponsored monitoring sites**
  - Include EPA, State, local site data if possible
  - Database structure coordinated with EPA, NARSTO, etc.
- **Web-based querying, sorting, graphing, mapping downloading capabilities**
  - Stakeholder group to define analytical capabilities



# Emissions Characterization

*Current and Recently-completed Projects*

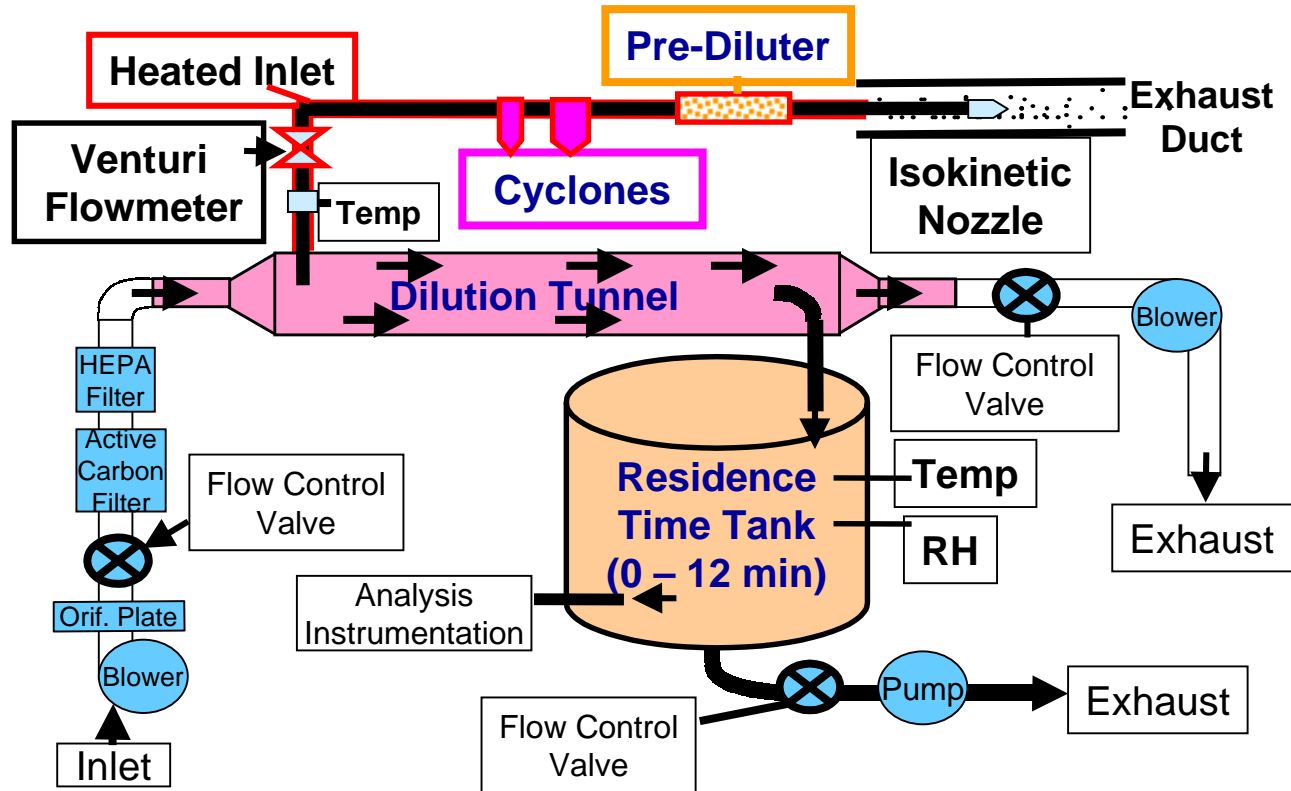


# Characterization of Primary PM<sub>2.5</sub> Emissions from Low-NOx Burners (*McDermott Technology Inc.*)

- **Higher unburned carbon in ultra-low NOx PM**
  - Overall ash LOI: 4.3% vs. 1.3%
  - PM<sub>2.5</sub> carbon: 45% vs. 7%
- **Decrease in ESP efficiency with ultra-low NOx**
  - 99.3% vs 99.9%
  - Associated with greater rapping re-entrainment
- **Most volatile trace elements (As, Se) enriched in finest particles**



# CMU Dilution Sampler





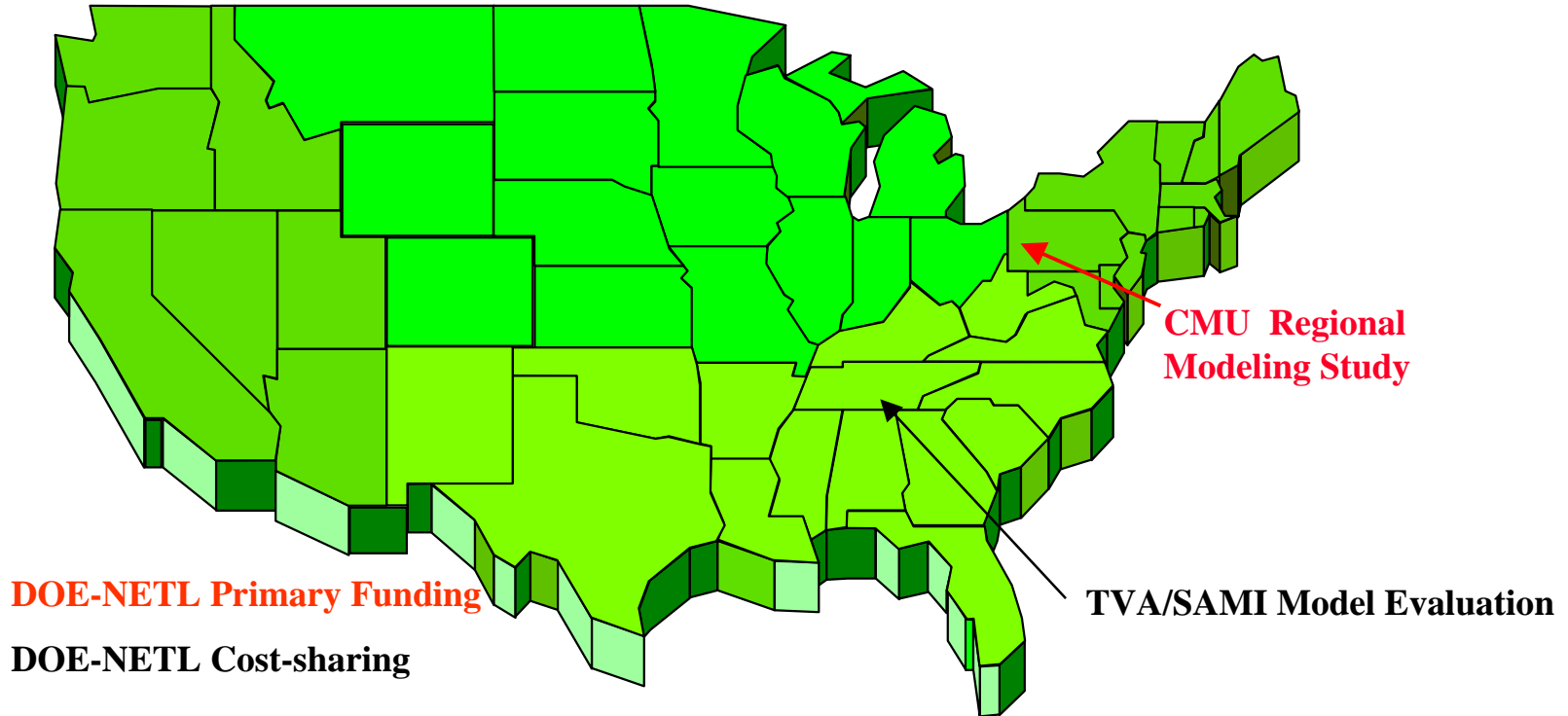
# CMU Dilution Sampler Development

- Characterize PM<sub>2.5</sub> from 2-lb/hr Combustion Environmental Research Facility (CERF) at NETL-PGH
- Study formation of secondary fine organic aerosols
- Quantify sampling artifacts due to vaporization & condensation of semi-volatiles
- Optimize system for later sampling at power plants

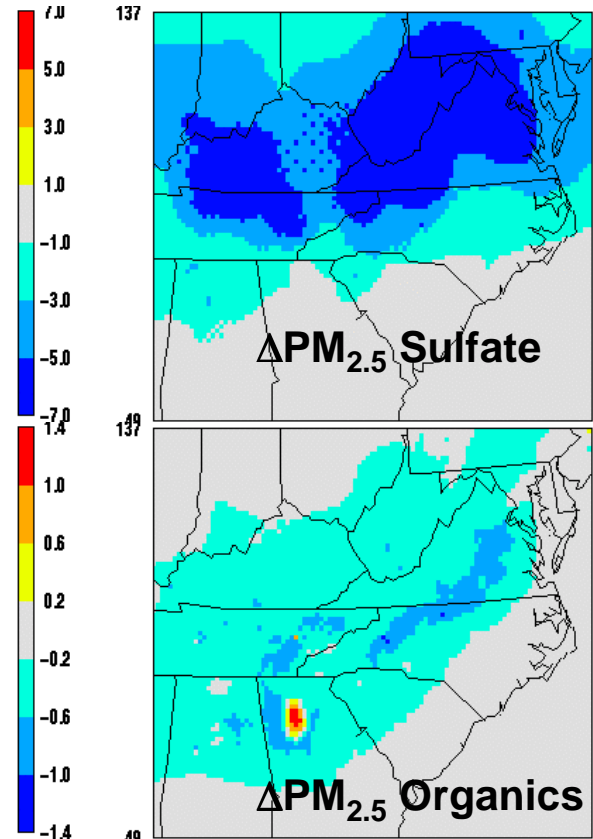
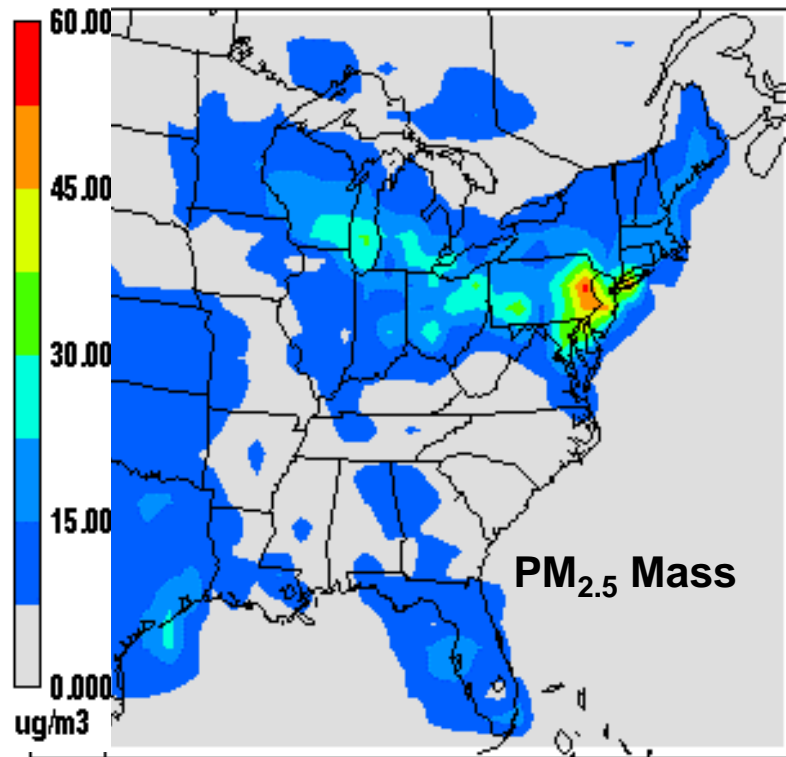


# Modeling and Evaluation

*Current and Recently-completed Projects*

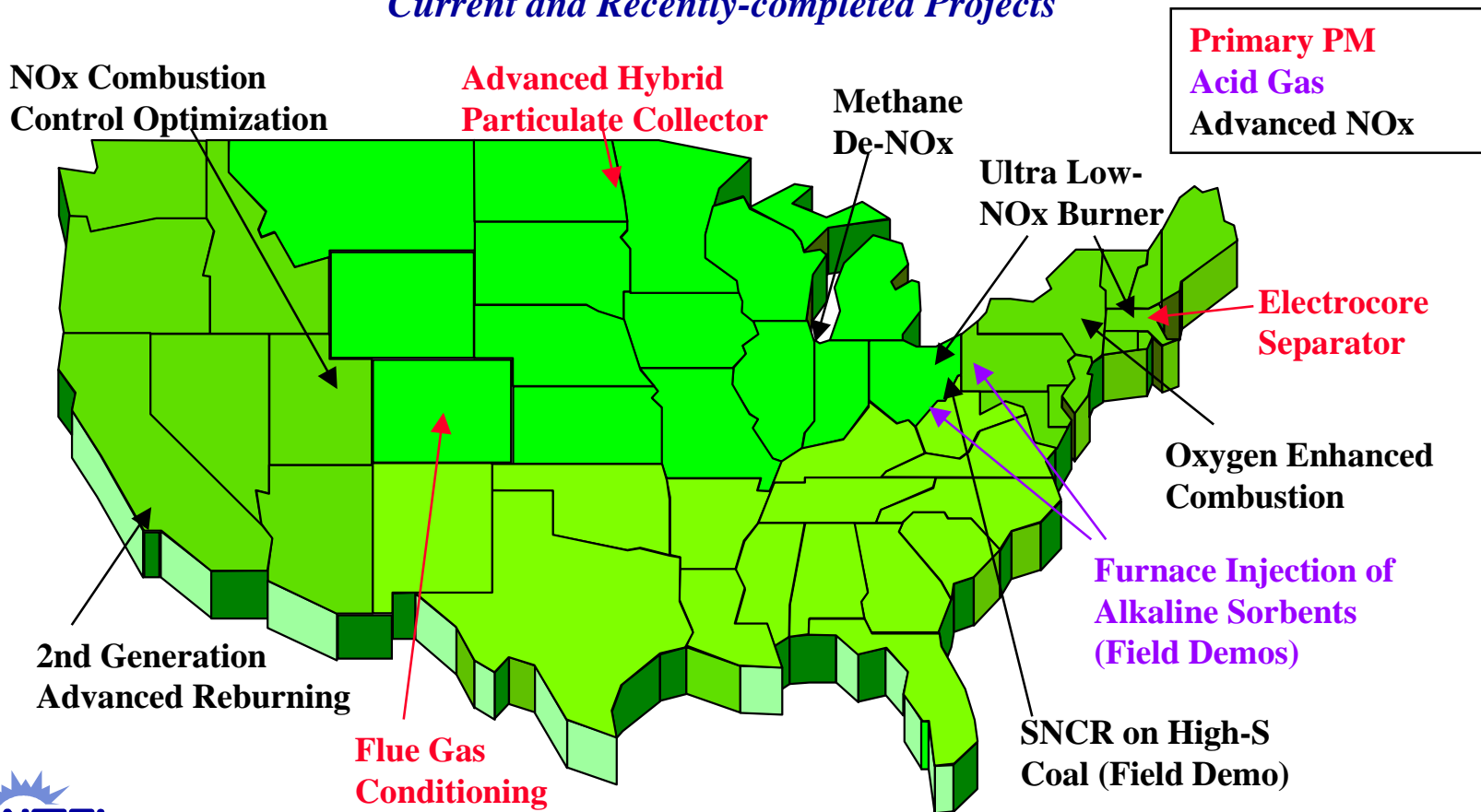


# Predicted $\text{PM}_{2.5}$ Aerosol for the Eastern US (*July 1995*)



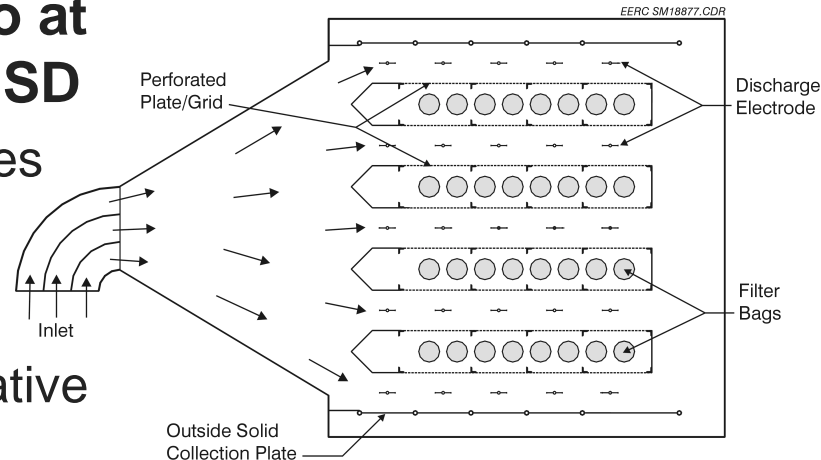
# Emissions Control Technology: PM, Acid Gas, & NO<sub>x</sub>

*Current and Recently-completed Projects*



# Primary PM Control Technology

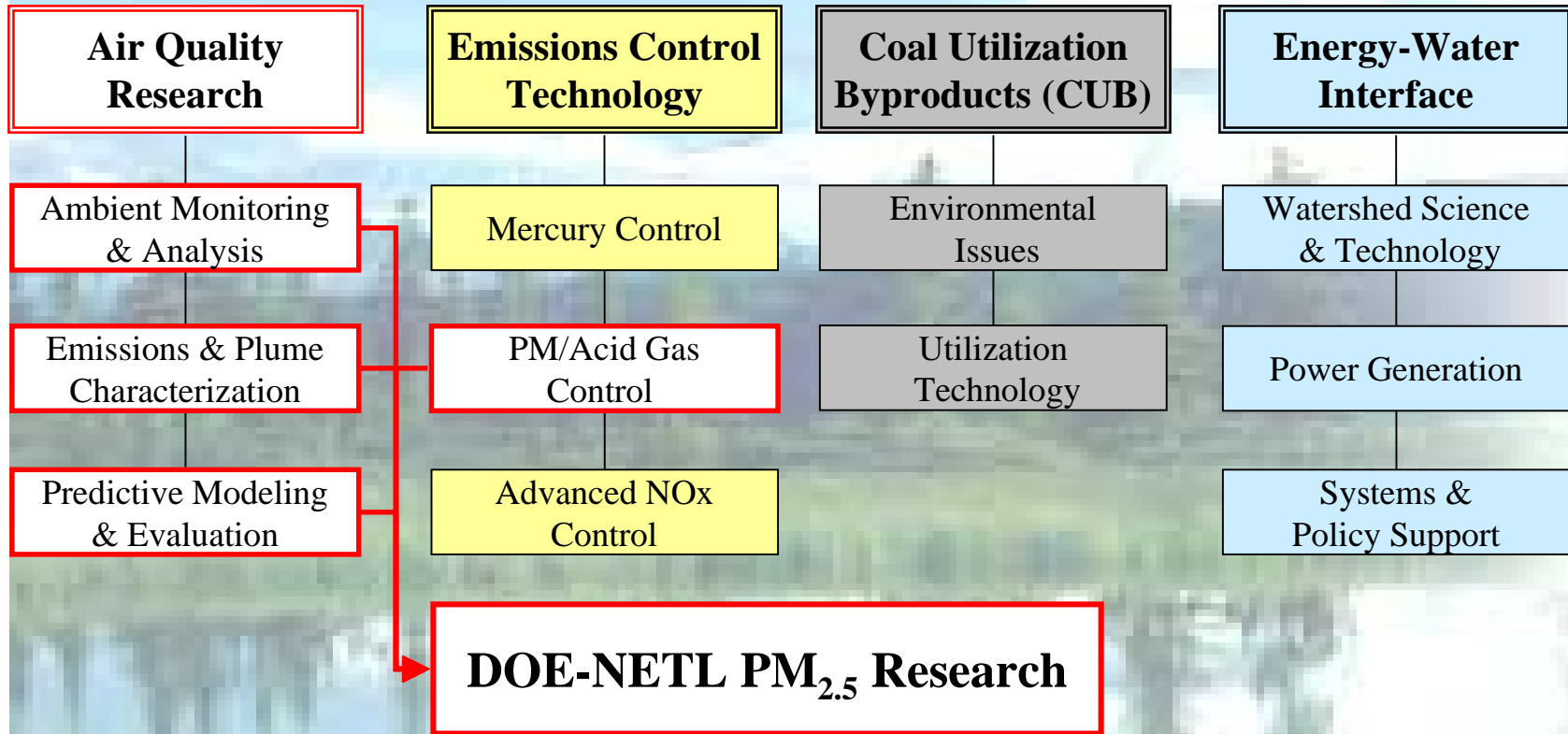
- **Advanced Hybrid Particulate Collector**
  - Developed by UND-EERC
  - Combination baghouse & ESP
  - Marketed as Advanced Hybrid™
- **Slipstream (9000 acfm) demo at Otter Tail Power, Big Stone, SD**
  - 99.99% removal of PM - all sizes
- **Full-scale (475MW) demo**
  - Power Plant Improvement Initiative



# Acid Gas Control Technology

- **Furnace Injection of Alkaline Sorbents for Sulfuric Acid Control**
  - Primary Performer: URS Group, Inc.
  - Environmental goal: reduce plume opacity & TRI emissions
  - Operational benefits: Control  $\text{SO}_3$  upstream of air preheater
- **Short-term (2 - 4 wk) field demonstrations**
  - First Energy, Bruce Mansfield Plant, Shippingport, PA
    - $\text{Mg}(\text{OH})_2$  sorbents provided best performance (~90% max)
  - AEP Gavin Station, OH
    - DOE Tests: August 2001 (~75%; SCR effects)
    - AEP full scale installation: May 2002

# DOE-FE Innovations for Existing Plants Program



# Future NETL Efforts - Air Quality Research & PM<sub>2.5</sub>

- **Environmental transformations of mercury**
  - Expand current monitoring, characterization, and modeling efforts to include Hg
  - Hg speciation changes in power plant plumes (EPRI)
- **Impact of air emission reductions on watersheds**
- **Develop new multi-pollutant control technologies**
- **Evaluate need/potential for PM health research (FY04?)**
  - Epidemiology studies in Pittsburgh area
  - Toxicology of sulfates and primary PM from power plants

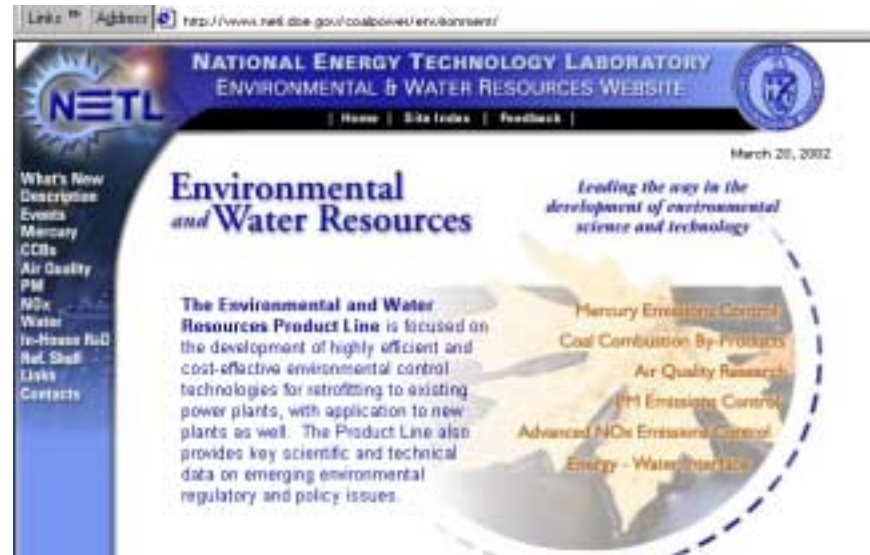




# For Further Information

- **NETL Environmental & Water Resources Website**

- <http://www.netl.doe.gov/coalpower/environment/>



- **NETL PM<sub>2.5</sub> Conference Proceedings - April 9-10, 2002**

- <http://www.netl.doe.gov/publications/proceedings/02/PM25/>

